Chapter 9
Methods of Assessing Risk

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Components of Risk Assessment

Introduction

Assessing ecological risk is complex. For example, how does one evaluate the risk of wildfire in an urban interface area or the spread of *Phytophthora lateralis* in a watershed? What is the objective and what is the potential for reaching that objective? Is it elimination of all risk, or some reduction in risk? What actions are possible? What is the cost of implementing those actions? What is the risk if nothing is done? Reducing risk assessment to four key elements helps to simplify the concept and evaluate alternatives for mitigation. The four essential elements of risk are: value, hazard, susceptibility, and exposure (fig. 9.1). Removing any of the four elements results in eliminating risk. The elements are interconnected and make up a "risk environment." Altering any element (risk management) alters the risk environment.

Four Elements of Risk

Value—To have risk, value must be involved. Port-Orford-cedar is valued for its utility, beauty, scarcity, and ecological function. Native American groups within the Port-Orford-cedar region use the tree for many purposes. The Japanese have, in the past, placed a high value on the fine-grained, light textured wood. Port-Orford-cedar has been economically valued in the United States for its strength and resistance to decay. In the 1930s, concern about past and current harvest rates by the public and the Forest Service led to the establishment of "preserves." These areas, now known as the Port-Orford-cedar and Coquille River Falls Research Natural Areas, were established in 1936 for scientific investigation, aesthetics, recreation, and concern for harvest rates, not for protection from *P. lateralis* (Tucker and Milbrath 1942).

If Port-Orford-cedar had no value, whether social, economic, ecologic, or spiritual, there would be no concern for its future. Spread of *P. lateralis* would be of no concern.

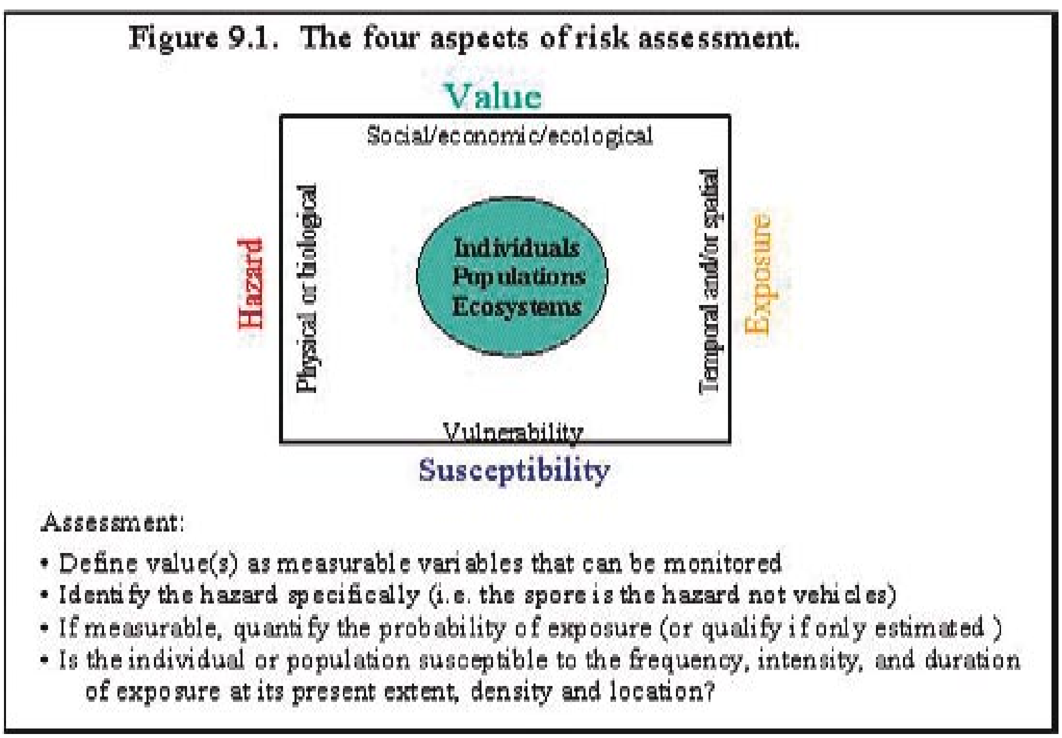

Figure 9.1—The four aspects of risk assessment

Hazard—*P. lateralis* is the hazard. It infects and kills trees. It is spread by vehicles, animals, and humans through infested soil and water; streams and roads act as corridors and habitat. On a large scale, it is highly unlikely that the hazard (disease) could be eliminated. Because of the flexibility in reproductive behavior, involving four methods of sexual and vegetative reproduction, elimination by direct action (i.e., applying pesticides) would be extremely difficult. The disease may be eliminated if the host – the Port-Orford-cedar – were eliminated, but that would not likely be tolerated by the public, and would change the ecological systems in which it occurs. Therefore, any attempt to eliminate the hazard on a large scale would be economically, socially, and biologically prohibitive.

Susceptibility—Susceptibility is a measure of the vulnerability of the object of value to the hazard. Some degree of resistance appears to be present in natural populations of Port-Orford-cedar, and may be enhanced genetically. The Port-Orford-cedar resistance and breeding program is working to produce genotypes with reduced susceptibility.

Currently most infections result in death. As research and development toward resistance proceeds, an appropriate, aggressive, operational assumption is that all individuals are susceptible and that infection is proportional to density of *P. lateralis* propagules.

Exposure—Exposure is an expression of the frequency, intensity, and duration that the host (Port-Orford-cedar) is in contact with the hazard (*P. lateralis*). In risk assessment, exposure must account for both time (temporal aspect) and location (spatial aspect). For example, if spores are deposited along a road once, the “frequency” of exposure is smaller than if many vehicles drive along a road, each depositing spores along the way. In another example, if vehicles are washed after leaving infested sites and before entering uninfested sites, the spore load is decreased and the “intensity” is decreased. Spatially, extent, location, and juxtaposition can be used to quantify exposure. Exposure is increased when an uninfested stand is adjacent to an infested stand (juxtaposition). Quarantine is primarily a spatial strategy whereby infested or non-infested areas are isolated. The extent of the pathogen is then minimized by using information on location and juxtaposition. Most strategies manipulate a combination of temporal and spatial occurrences of *P. lateralis*.

The Social Context of Risk

Practical goals concerning risk are determined within social constraints. Limits exist on what society is willing to pay and the level of risk they are willing to accept. For example, it is socially desirable to eliminate all traffic fatalities; however, regardless of the high value society places on life, traffic fatalities are accepted as part of the risk associated with driving. The resources that society is willing to commit, the restrictions they are willing to endure, and the risks they are willing to assume are value dependent (Cooray 1985). When stressed, individuals will violate restrictions and accept increased risk. If a speed limit of 15 mph is shown to reduce traffic fatalities to near zero, some individuals, in a hurry, will drive faster and increase their risk of a fatal crash. Complete freedom, no restrictions and no risk, represents the most desirable scenario but the least attainable. Determining a strategy to balance restrictions with risk may be the next best option (fig. 9.2). With regard to control of *P. lateralis*, it is nearly biologically impossible to eliminate the pathogen on a large scale and it is unlikely to be economically feasible or socially acceptable.

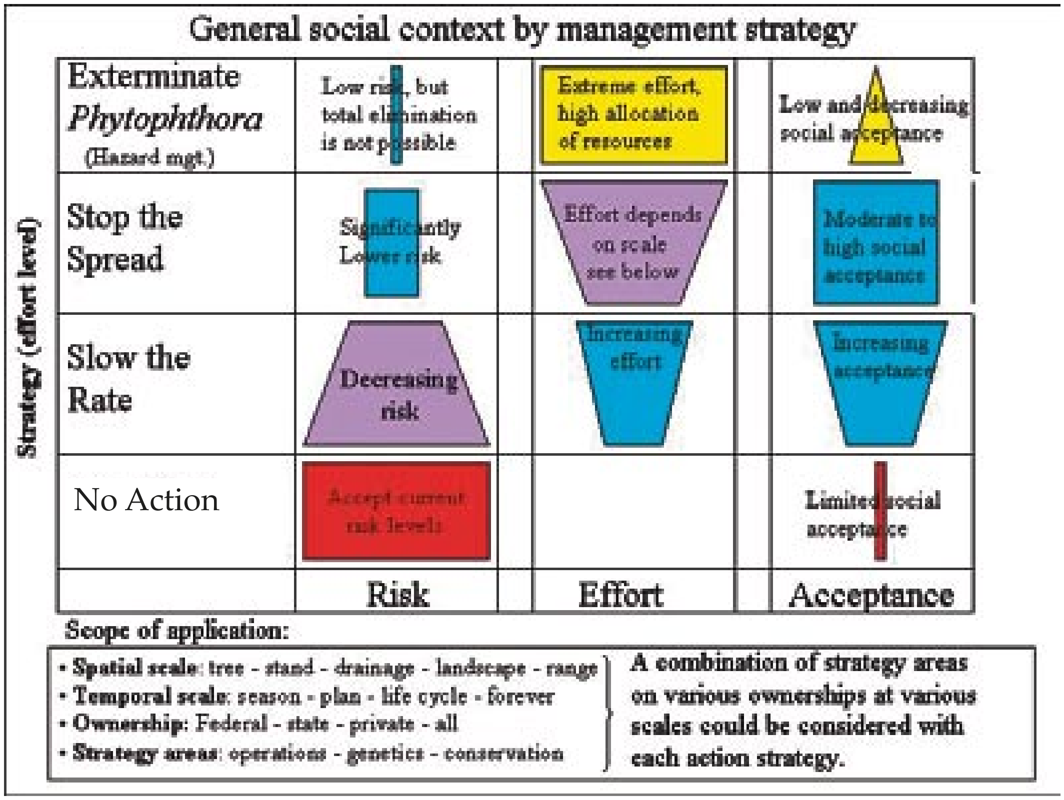

Figure 9.2—The relationships of strategy to the risk, effort, and acceptance of implementing that strategy

Range of Possible Strategies

Figure 9.2 shows a range of possible strategies and qualifies the relationships between risk, effort, and acceptance. Some combination of any or all strategies may be an appropriate approach for attaining the range-wide, long-term goal of maintaining the ecological presence and economic viability of Port-Orford-cedar.

No-Action

A no-action strategy accepts the results of the ecological dynamics between Port-Orford-cedar and *P. lateralis* within a changing environment. Historic experience with introduced pathogens infecting five-needle pines, elm, and chestnut indicates probable widespread mortality (even with control efforts) and diminished ecological and economic function (Merkel, 1905; Swingle, et al, 1949). Given that resistance to the pathogen appears only sporadically within natural populations of Port-Orford-cedar, the natural selection process in the genetic evolution of this tree species is unlikely to contribute significantly toward the goal of reducing the risk of infection in the short term.

Slow the Rate of Infection

The rate of infection may be slowed by low-effort, active or passive conservation strategies. These may include: 1) quarantining (isolating) infected or healthy trees, stands, or drainages; 2) washing vehicles; and 3) restricting seasonal access in certain areas. While isolating uninfested stands may lower their risk for exposure, this probability may be reduced if surrounding landowners do not cooperate. Operational measures such as washing vehicles or restricting access to areas has been a part of coordinated forest efforts and can slow infection rates (Goheen et al. 2000).

Stop the Spread

Scale is important to consider when defining a level of effort for "stopping the spread." If stopping the rate of spread is defined at the individual tree level, rather than by stand or drainage, then not one additional tree would become infected. This strategy would be impossible to monitor and difficult to achieve, but would have a high probability of lowering infection rates. Strategies might include increasing access restrictions, initiating more control measures, and performing intense sanitation (removal of host Port-Orford-cedar trees, especially along roadsides). Social acceptance may be limited with some of these measures.

Eliminate *P. lateralis*

Eliminating *P. lateralis* from the range of Port-Orford-cedar would be a long-term strategy and would require collaboration among all agencies, corporations, and private landowners. This situation may be similar to eliminating all traffic deaths. Developing methods to directly destroy *P. lateralis* would likely occur, as well as implementing methods to prevent reintroduction. The risk of *P. lateralis* to Port-Orford-cedar would be minimal to zero; however again, the necessary chemical, natural, and thermal methods might make these strategies socially unacceptable. Their effectiveness would be difficult and costly to monitor. Increasing restrictions and costs may lead to significant lowering of social acceptance.

Evaluating Risk for Port-Orford-Cedar

It has been established that Port-Orford-cedar has value. *P. lateralis* presents a hazard to Port-Orford-cedar. Currently almost all Port-Orford-cedar trees are susceptible to this hazard upon exposure. The immediate opportunity to manage risk in this situation comes from minimizing exposure of Port-Orford-cedar to *P. lateralis*. A long-term strategy includes breeding Port-Orford-cedar for reduced susceptibility (increased resistance) to *P. lateralis*.

The first step in a risk analysis is determining which of the four key elements (value, hazard, exposure, susceptibility) has potential for management. In the case of Port-Orford-cedar, current opportunities exist for management of exposure.

Table 9.1 lists the factors that are correlated with Port-Orford-cedar exposure to infection. Each factor has been subjectively rated on importance to risk. The factors are rated high (H), medium (M), or low (L) and are assigned a quantitative value of 3, 2, or 1, respectively. Each factor is also rated and assigned a quantitative (3, 2, or 1) value based on our ability to manage or control it. A "rank" is determined by adding the two quantitative ratings. The highest-ranking factors (in this case, the 6s) have a high risk along with a high level of ability to lower that risk. These factors would be a logical choice to use in a risk assessment.

The physical factors span the range in importance from low to high, but there is little opportunity to manage them, so the "control" rating is usually low. The risk from biological factors, roads and road related vectors, and harvest/extraction is often rated high or medium, and opportunities to control exposure often exist. The highest ranked factors are adjacent infection, recent dead Port-Orford-cedar, road surface, culverts, ditches, tree harvest method, and bough harvest. These deserve high priority when a risk analysis is done.

The next step requires defining a risk rating for each of the factors being considered. Suppose proximity to roads and proximity to infested areas are the factors being considered. We can define high-risk areas as those closer than 50 feet from a road. We may assign a quantitative value of 2 to these areas. Low risk areas would lie greater than 50 feet from a road and may have a quantitative value of 1. High risk with regard to distance from an infested area may be defined as less than 100 feet, and assigned a value of 2. And low risk would be more than 100 feet from an infested area, with a quantitative value of 1. Combining all combinations of the two factors would result in total risk values ranging from 2 to 4, with 4 being the highest risk.

The next step is to apply these risk categories to an area. Areas could be mapped using the Geographic Information System (GIS) to delineate each of the risk areas, the 2s, 3s, and 4s. At this point, a map is available showing the risk areas and the next decision is whether or not to mitigate the risk and what methods are available.

Table 9.1—Factors that influence risk of infection of Port-Orford-cedar by *P. lateralis*, their level of risk (high, medium, or low), and our ability to change or control the level of risk (high, medium, or low)

Influencing Factor		Risk	Control	Rank*
Physical factors	Geologic rock type	L	L	2
Average rank = 2.7	Elevation	L	L	2
	Aspect	L	L	2
	Slope steepness	M	L	3
	Slope position microtopography	M	L	3
	Slope position macrotopography	M	L	3
	Soil moisture	M	L	3
	Drainage density	M	L	3
	Proximity to stream or water or flood - plains	H	M	5
	Annual Rainfall	L	L	2
	Average annual temperature	L	L	2
Biological factors	Plant association	H	L	4
Average rank = 4.5	Port-Orford-cedar density, extent, juxtaposition	M	H	5
	Density or cover of other hosts	M	H	5
	Adjacent infection	H	H	6
	Adjacent infection of cultivars	H	L	4
	Recent dead (density and proximity)	H	H	6
	Seral stage	L	H	4
	Animal populations as vectors	L	L	2
Roads and road related vectors	Road density	H	M	5
Average rank = 4.8	Road surface	H	H	6
	Proximity to road	H	M	5
	Other road design factors (usually drainage)	M	M	4
	Culverts	H	H	6
	Ditches	H	H	6
	Traffic density	H	M	5
	Traffic type	M	H	5
	Right-of-way agreements	M	L	3
	Off-road vehicle traffic	H	M	5
	Trails (same as roads)	M	H	5
	Fishing traffic	L	L	2
Harvest /Extraction	Harvest frequency	M	H	5
Average rank = 5.3	Harvest method	H	H	6
	Bough harvest	H	H	6
	Mining	H	L	4
Opportunities to control exposure	Ownership pattern	M	L	3
Average rank = 3.0	Land allocation	L	M	3

*Quantitative values for risk and control were assigned: 1 = low, 2 = medium, 3 = high. The rank is the sum of the risk and control values.

After the Risk Analysis

Additional factors must be considered after the risk analysis to determine whether or not action is to be taken and if so, what action. If the cost of treatment is high, it may prohibit any action regardless of the risk. Social acceptance must also be considered, especially on public land.

Quantification of Risk Factors

As risk analyses become more sophisticated, the values assigned to help quantify risk will become more accurate.

For example, Jimerson (1999) has shown a highly significant difference between infested and uninfested stands based on slope position. In California, stands in riparian areas are much more likely to have Port-Orford-cedar infected with *P. lateralis*. Infested and uninfested stands are significantly different in mean distance from roads. Infested stands average 52 feet and uninfested stands 139 feet from a road. Distance from the Pacific Ocean (an integration of several environmental factors, including fog, moisture, temperature, etc.) and elevation also differed between infested and uninfested stands. Mean distance from the ocean was 14 miles for infested and 24 miles for uninfested stands. Mean elevation for infested stands was 475 feet and for uninfested stands, 866 feet. As means, these values can be used to assign high-risk and low risk categories.

Regression analysis expresses the relationship between two or more continuous variables, for example, the percentage of a stand that is infested and the elevation of that stand. As presented above, the average uninfested stand is higher in elevation than the average infested stand. If we could sample several stands and develop a model (regression) of the relationship between these two variables, we could assign stand risk values more precisely than simply high risk-low risk.

In biological systems, usually several variables interact with each other. For example, elevation and distance from the ocean may give a better estimate of infested stands than either variable alone. This could be modeled with multiple regression techniques.

Most relationships are not likely to be linear and may display thresholds, limits, maximums, and minimums. In such cases, even when the relationship is relatively weak, it may be useful.

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